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(54) Engine monitoring.

(57) Abnormal start conditions, such as hot starts or hung starts, in an aircraft gas-turbine engine are monitored by deriving signals indicative of spool speed, engine temperature and fuel flow. A processor (20) receives these signals and derives an indication of the rate of change of engine temperature. Signals indicative of whether the aircraft is on the ground or in the air are derived from an air speed sensor or undercarriage pressure switch (21). The processor (20) monitors the relationship between these signals to determine when the relationship between them is indicative of an abnormal start condition and indicates this on a display (2) such as by flashing the display (5) of engine temperature.

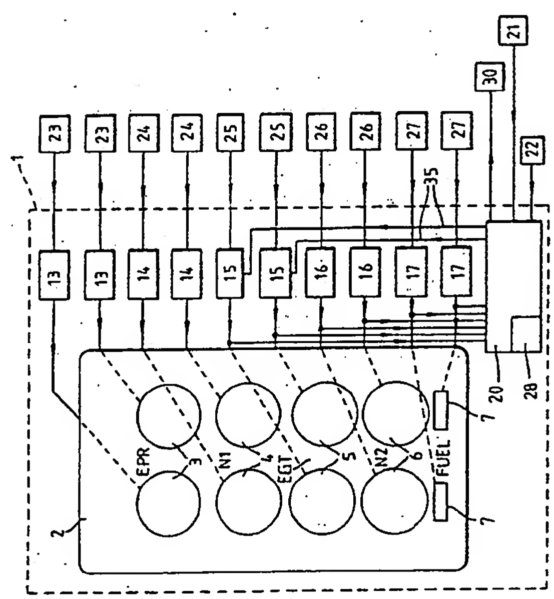

Fig.1

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Engine Monitoring

This invention relates to engine monitoring apparatus for detecting abnormal start conditions of a gas-turbine engine including a sensor for deriving a first signal indicative of spool speed, and a sensor for deriving a second signal indicative of engine temper... .re.

During start-up procedures of a gas-turbine engine, the pilot or flight engineer (where the engine is in an aircraft) monitors a number of instruments giving details of various engine characteristics, such as N 1 and N 2 spool speeds, exhaust gas temperature EGT, and fuel flow. It is important for the engine operation to be carefully monitored during start-up because gas-turbine engines can be prone to abnormal or 'hot' starts which can lead to irreparable damage to an engine at a cost of up to about one million pounds. Some aircraft operators experience several such hot starts each year.

It will be appreciated that, at the time of starting the engine, the flight crew are faced with many other tasks as well as monitoring for hot starts. With some engines it can take up to a minute for the engine to start and for the risk of hot start to be passed. The detection of hot start relies on the flight crew's ability accurately to assess the instrument readings, to remember the various limits of operation that may be indicative of a hot start and to identify exceedance of these limits and take appropriate action. The flight crew's ability to do this whilst undertaking other activities can be restricted.

It is an object of the present invention to provide engine monitoring apparatus and methods that can be used to detect abnormal start conditions in gas-turbine engines.

According to one aspect of the present invention there is provided engine monitoring apparatus of the above-specified kind, characterised in that the apparatus includes a processor that receives the first and second signals, and that the processor monitors the dynamic relationship between the first and second signals such as to determine when the relationship is indicative of an abnormal start condition, and signals in real time an indication of such abnormal start condition.

The apparatus may include a sensor for deriving a third signal indicative of fuel flow. The apparatus may include a display that provides a visual display of spool speed and engine temperature or fuel flow. The processor preferably signals an abnormal start condition on a visual display such as by flashing the visual display such as the visual display or engine temperature.

Where the apparatus is for an aircraft engine, the apparatus may include a sensor that provides a fourth signal indicative of whether the aircraft is on the ground or in the air, the processor receiving the fourth signal and utilising the fourth signal in determining when the relationship is indicative of abnormal start conditions.

The sensor for providing the fourth signal may include an air speed sensor and or alternatively a sensor for sensing pressure on the aircraft undercarriage.

In this way, the user of the engine can be alerted to a possible abnormal start condition, enabling him to take remedial action, with a reduced risk of such an abnormal start condition being overlooked.

Monitoring apparatus for an aircraft gas turbine-engine, and its method of operation, in accordance with the present invention, will now be described, by way of example, with reference to the accompanying drawings, in which

Figure 1 shows the apparatus schematically; and

Figure 2 is a flow chart illustrating operation of the apparatus.

With reference to Figure 1, the monitoring apparatus is included within an otherwise conventional engine display system, indicated generally by the numeral 1. The system 1 has a front display panel 2 with various light-emitting diode display regions 3 to 7 on which are displayed respectively engine pressure ratio EPR, spool speed N 1, engine exhaust gas temperature EGT, spool speed N 2 and fuel flow. Each of the display regions 3 to 7 is duplicated on the panel 2 in order to enable information about two gas-turbine engines to be displayed side-by-side.

Each of the display regions 3 to 7 is driven by respective driver unit 13 to 17 which receive inputs from respective sensors 23 to 27 associated with each engine and process the sensor outputs into a suitable form for driving the display regions.

The outputs from the driver units 15 to 17 providing the EGT, N2 and fuel flow information are also supplied to a processing unit 20. The processing unit 20 also receives input signals from an outside air temperature detector 21 and from a flight/ground detector 22 (this may, for example, be an undercarriage pressure switch or an airspeed detector).

The processing unit 20 includes a memory store 28 in which is sotred a model of the normal relationship between temperature EGT and spool speed N 2 at different fuel flows and outside air temperatures. Different models may be employed

according to whether the engine is on the ground or in the air, this being indicated by the output of the detector 22.

The processing unit 20 monitors the dynamic relationship between engine temperature EGT, fuel fuel and spool speed N 2, comparing this against the model stored in the store 23. In particular, the processing unit 20 derives a signal representing the rate of change of engine temperature. Generally, the temperature tracks turbine speed, an increase in EGT being accompanied by an increase in N 2. If the processing unit 20 detects that these operational conditions fall outside those of the stored model, it signals this in real time to the flight crew by supplying a signal on line 35 to the appropriate EGT display driver 15, according to the engine that is malfunctioning, to cause the display region 5 to flash. It is also possible to supply a signal to a separate alarm 30, such as an audible alarm or an indicator on a separate anunciator panel. The flashing of the display region 5 causes it to become conspicuous to the flight crew, even if the display panel is not viewed directly because, in the parafoveal region of the eye a changing image is more readily noticeable.

With reference to Figure 2, there is illustrated steps in the operation of the processing unit 20. The algorithm used in the PROCESS step is unique to each type of engine and can be provided the engine manufacturer. In general it will be necessary to generate first derivatives of the spool speeds N1, N2, N3 although derivatives of other engine or aircraft parameters may be needed for some algorithms. Examples of parameters utilised in the algorithm are shown as FUEL FLOW, EGT/ITT (inter turbine temperature), OIL TEMPERATURE, OIL PRESSURE, OIL QUANTITY, N1, N2, N3, $\dot{N}1$, $\dot{N}2$, $\dot{N}3$. It may not be necessary to use all of these parameters, or additional parameters may be needed for other algorithms. Limits are set according both to predetermined absolute levels and to levels determined by the PROCESS step. One or more COMPARISON steps are performed and if the limits are exceeded, an abnormal start signal is generated.

In some applications of gas-turbine engines, the detection of an abnormal start could be used to interrupt fuel flow automatically to the engine. This, however, is considered generally undesirable in aircraft applications where engine shut-down can be dangerous.

An abnormal start condition is one which eventually increases the probability of damage or distress to the engine. In some circumstances, abnormal start conditions can occur but the engine continues to start. This may not lead to immediate failure of the engine but can lead to increased fatigue and thereby reduce its safe operating life. The apparatus of the present invention enables abnormal start conditions to be detected at an early stage, before damage or distress is caused to the engine.

In addition to the detection of 'hot starts' the processing unit 20 can be arranged to detect other abnormal start conditions, such as a 'hung start'. Because different engines operate in different ways the monitoring apparatus may function in different ways, although, in general the processing unit will need to receive inputs indicative of engine temperature, fuel flow and spool speed.

The processing unit 20 need not be a separate unit but could, for example, be provided by a part of the processing capability of one or more of the display driver units 13 to 17. The display driver units 13 to 17 themselves could be provided by a single unit with a multiplexed output.

Claims

1. Engine monitoring apparatus for detecting abnormal start conditions of a gas-turbine engine including a sensor for deriving a first signal indicative of spool speed, and a sensor for deriving a second signal indicative of engine temperature, characterised in that the apparatus includes a processor (20) that receives the first and second signals, and that the processor (20) monitors the dynamic relationship between the first and second signals such as to determine when the relationship is indicative of an abnormal start condition, and signals in real time an indication of such abnormal start condition.

2. Engine monitoring apparatus according to Claim 1, characterised in that the apparatus includes a sensor for deriving a third signal indicative of fuel flow.

3. Engine monitoring apparatus according to Claim 1 or 2, characterised in that the apparatus includes a visual display (2) that provides a visual display of spool speed, and engine temperature or fuel flow.

4. Engine monitoring apparatus according to any one of the preceding claims, characterised in that the processor (20) signals an abnormal start condition on a visual display (2).

5. Engine monitoring apparatus according to Claims 3 and 4, characterised in that abnormal start condition is signalled by flashing the visual display (2).

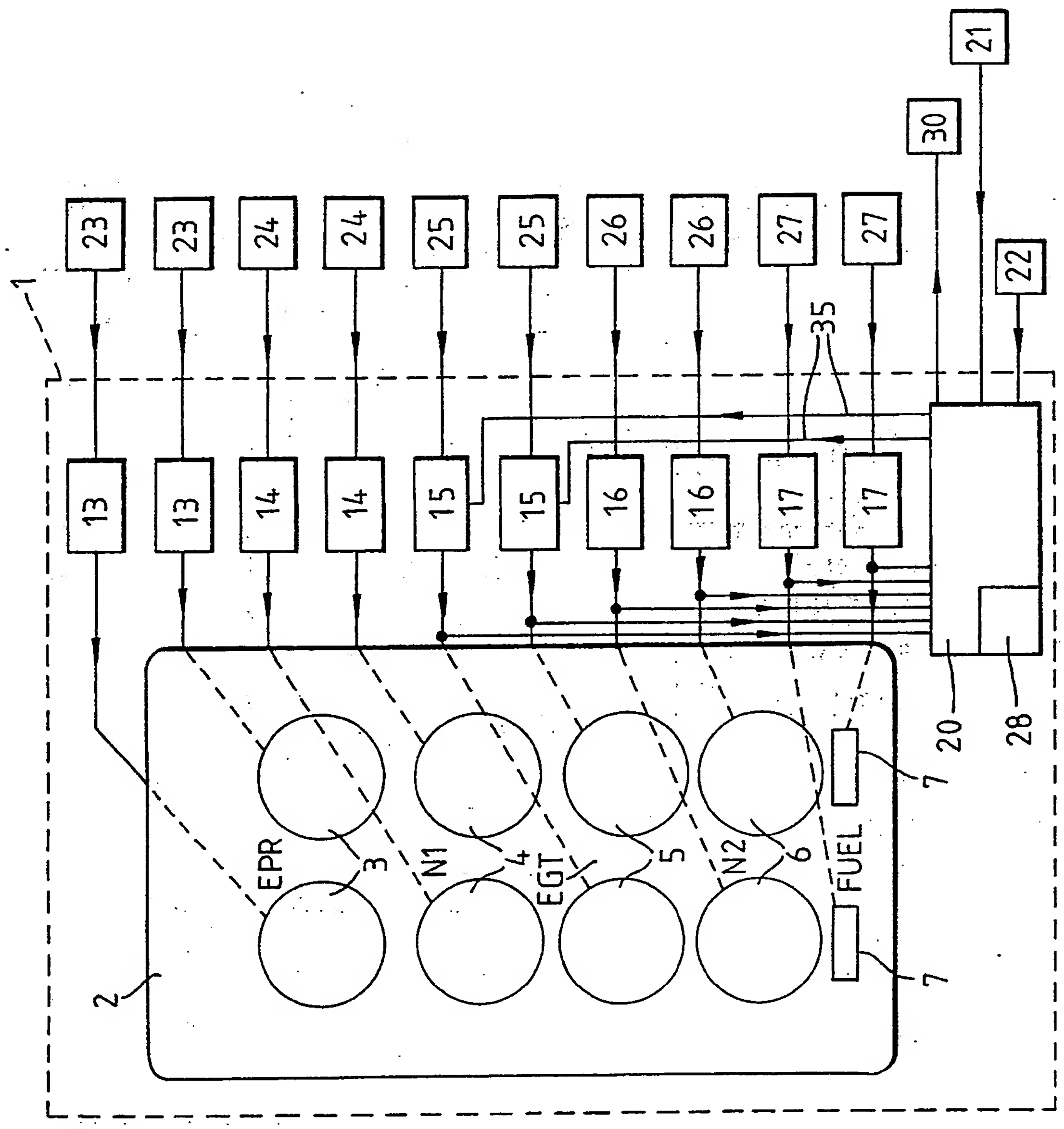
6. Engine monitoring apparatus according to Claim 5, characterised in that abnormal start condition is signalled by flashing the visual display of engine temperature.

7. Engine monitoring apparatus according to any one of the preceding claims, characterised in that the processor (20) derives an indication of the rate of change of engine temperature.

8. Engine monitoring apparatus for an aircraft engine according to any one of the preceding claims, characterised in that the apparatus includes a sensor that provides a fourth signal indicative of whether the aircraft is on the ground or in the air, and that the processor (20) receives the fourth signal and utilises the fourth signal in determining when the relationship is indicative of abnormal start conditions.

9. Engine monitoring apparatus according to Claim 8, characterised in that the sensor for providing the fourth signal includes an air speed sensor.

10. Engine monitoring apparatus according to Claim 8 or 9, characterised in that the sensor for providing the fourth signal includes a sensor for sensing pressure on the aircraft undercarriage.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17
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EPR
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N1
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EGT
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N2
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FUEL
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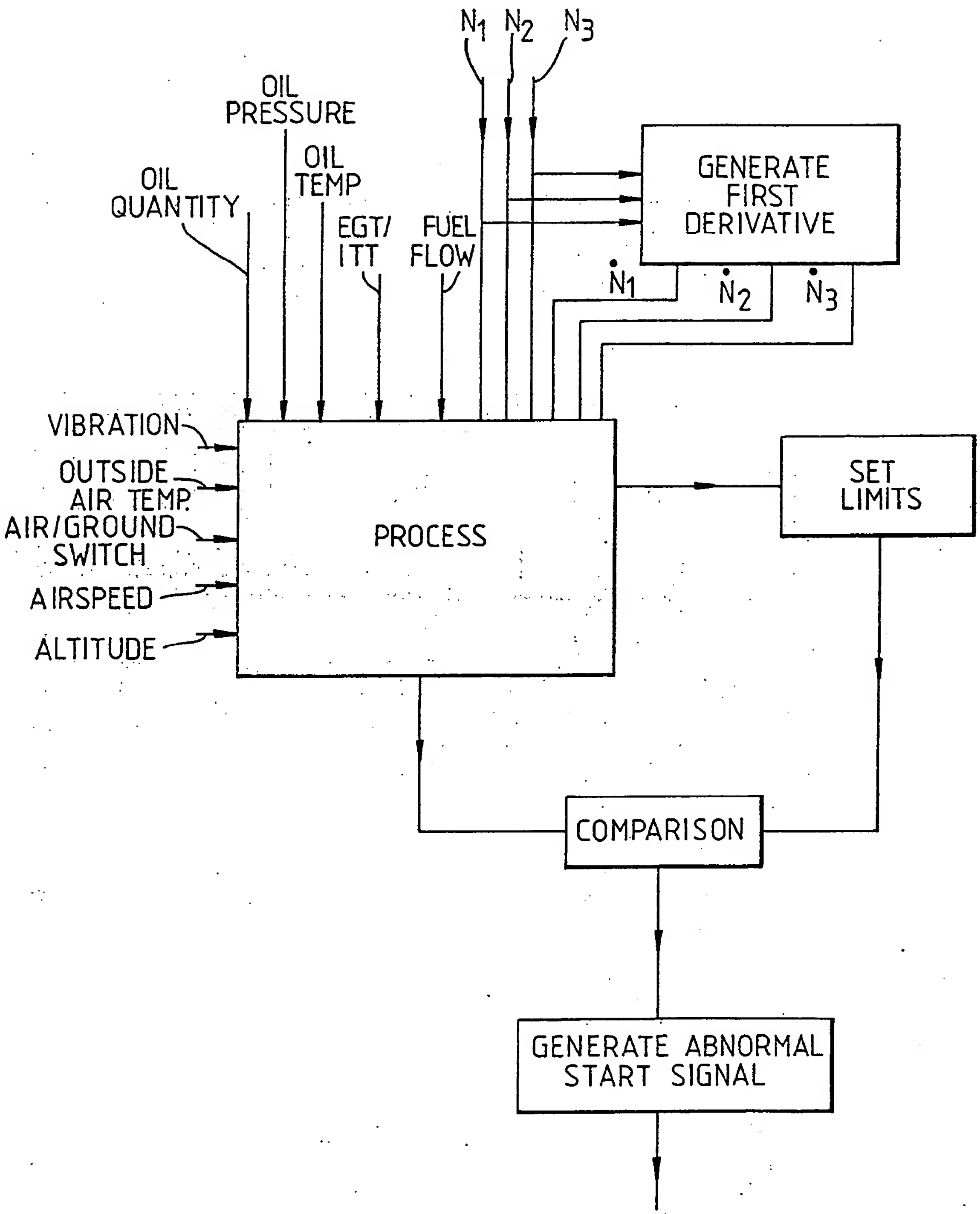
7

Fig.1

Fig.2


N1
N2
N3
OIL PRESSURE
OIL TEMP
OIL QUANTITY
EGT/ ITT
FUEL FLOW
GENERATE FIRST DERIVATIVE
Ṅ1
Ṅ2
Ṅ3
VIBRATION
OUTSIDE AIR TEMP.
AIR/GROUND SWITCH
AIRSPEED
ALTITUDE
PROCESS
SET LIMITS
COMPARISON
GENERATE ABNORMAL START SIGNAL